

Blockchain: A Workable Distributed Energy Exchange Framework for Prosumers in a Micro-Grid

Haseen Ullah¹, Muhammad Uzair², Asfandyar Khalid³, Junaid-Ur-Rehman⁴

^{1,2,3,4}Department of Electrical Energy System Engineering, US-Pak Center for Advanced Studies in Energy (USPCAS-E), UET, Peshawar, Pakistan

haseen@myself.com¹, uzair.uetpeshawar@gmail.com², asfandyarkhalid@ymail.com³

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Abstract— The rampant increase in demand of electrical energy with raising life standards owing to technological advancement coupled with already stressed power system infrastructure, has exacerbated the energy regime. Chasing this demand gap, many countries are heavily investing in non-renewable generating plants. On one hand, it will worsen the global climatic condition, while on the other hand it will further tense the power transmission and distribution systems. A better alternative is to invest in renewable DG's along with the culture of energy sharing. Currently, net metering is widely used for energy sharing, yet the introduction of Blockchain will revolutionize this industry. A dedicated analysis based on payback, break-even point, levelized cost of energy, and rate of return has been carried out for both net metering and Blockchain system to find a workable distributed transactive energy exchange framework for con(pro)sumers in a micro-grid.

Keywords— Blockchain, Net-Metering, Payback period, Levelized Cost of Energy, Break-Even Point.

I. INTRODUCTION

In the twenty-first century, electricity is regarded as a critical socioeconomic engine. The use of electrical energy has expanded dramatically as people's living standards have materially elevated. The mushrooming load-demand can't be met by a solo component like a utility company, we've to come up with innovative strategies to meet it. Consequently, we decided to pool our energy resources aided with latest technologies. In this regards, many new concepts and approaches in the electrical market emerged for the sharing of energy. Initially, the mechanism of a Net Metering System (NMS) for sharing excess energy has been introduced in recent years. But now the Blockchain System (BCS) has been also introduced in addition to the NMS for a decentralized pooling, a concept borrowed from crypto currencies. Not only will this new technology modernize the energy industry, but it will also end utilities' monopolies. Conventionally, solar power system installers are rewarded for the kWh they contribute to the grid through net-metering [1]. The approach is to create maximum energy from the sun during the day and in favourable conditions and add it to the grid, while importing energy back when needed

at night or in unfavourable conditions. This is one approach to relieve grid pressure, meet power deficits, and eliminate the costly backup system while saving money on utility bill. In contrast, blockchain is a relatively new internet that empowers con(pro)sumers to sell surplus solar energy to others on a secure platform in a very active viable exchange[2]. In terms of decreasing utility monopolies and boosting energy sharing among consumers and prosumers, it outperforms the net metering mechanism. In this research, we intend to assess the infrastructure and architectural aspects of a micro grid based on NMS and BCS. A range of economic measures are utilised to analyse each system for this investigation.

II. LITERATURE REVIEW

The power grid is rapidly evolving, current technology has improved the usage of advanced control methods, and next-generation grid technologies will require a focus on the integration of DERs with customers who can buy and sell electric energy in a seamless manner [4]. The growing load on power plants and transmission lines has cleared the way for distributed generation, utilising renewable energy sources (RES)[5]. Because renewable energy sources are inherently intermittent, harnessing them necessitates extensive technological and economic considerations[6]. As a result, exporting excess RES energy to the utility grid and receiving credit for it is more feasible[7]. It is advantageous to both the consumer and the utility [8]. The technical considerations for exporting electricity to the grid have been thoroughly examined in [9], which includes a comparison of traditional and advanced smart metres. Because renewable penetration in the national grid is limited, it is preferable to exchange electricity among peers in close proximity, according to the paper. Procedures and mechanisms for sharing and trading electricity between customers and prosumers have been put in place after a lot of work. Trading via NMS and BCS will be the subject of our research.

Net metering, according to [10], is a policy aimed at encouraging the adoption of modest renewable energy systems for power generation. When a system owner generates extra power than they require during a certain passé, they are given retail credit for the amount of electricity they subsidise[10]. Import/export tariffs are typically imposed by regulators usually

favour utility corporations [11]. Furthermore, market competitiveness in the Net metre is unfavourable for all energy trading stakeholders except utility[12]. Despite the fact that prosumers profit more from net metres than consumers, the utility maintains its monopoly by dictating tariffs [11].

Blockchain for energy sharing is a recent field with little research. A detailed examination of the possibility of peer-to-peer communication may be found in [13]. In this study [14], Jianzhong described a comprehensive bidding mechanism for peer-to-peer systems, which featured the Elecbay energy exchange. While Ehmke [15] explains the scalability question in Blockchain lumps, he then suggested explicitly keeping the state of the system in the current block, but he goes even farther by including the relevant part of the existing system data in new transactions using Ethereum. Another credible paper [3] on the use of Blockchain in the financial sector, with a focus on supply chain management. Similarly, M. Condoluci says though data requirement for blockchain is enormous, yet the development of 5G can cater its demand [16]. In short, the literature review of Blockchain reflect that with all its complication the BCS is capable is bring revolution in energy market.

III. METHODOLOGY

The objective of creating a sustainable decentralised energy trading system using Blockchain or net metering has been set, recognising the huge benefits and importance of this technology in the future smart grid. Following an exhaustive literature review, we are now aiming to apply theoretical knowledge to build several scenarios that aid us in evaluating each system. For objectives of this study, we assumed a micro-grid with some pro(con)sumers who have specific solar generation and mentioned loads. For ease, we assume that the local micro-grid is connected to main grid; consequently, we consider the infrastructure that has to be changed or upgraded in the existing power structure for Net-metering system or Blockchain System are taken into account. Power, Control, Communication, and Business are the four layers that make up the infrastructure of NMS and BCS. After carefully assessing the cost per unit for both systems, a dynamic revenue generating model is created. The data supplied by the per unit cost and income model is thoroughly investigated using a variety of economic indicators. The results are correlated, culminating in a workable decentralised trading system for prosumers in a smart microgrid.

A. Payback Analysis

The time it takes to recoup the money invested is referred to as the payback period. It is best if the payback period is as short as possible. The payback for both NMS and Blockchain are investigated in this paper. We calculated payback by removing the salvage value from the capital cost of each system to arrive at net capital cost. The payback analysis is based on the capital investment and revenue generated by each system. Finally, by following a formula, we were able to obtain payback.

$$\text{Payback Period} = \frac{\alpha \sum_{i=1}^n G_i - SV}{\beta G_r}$$

Where,

- α Estimated system cost per unit watt
- i No. of Pro(Con)sumer 1, 2, 3 ... n
- G_i Installed Generation Capacity of ith pro(con)sumer
- r Depreciation's Rate
- y Expected Lifespan of the system in yrs
- SV Salvage Value of the system
- β Price per unit watt for sale
- Gr Yearly kWh Produced

B. Break-Even Analysis

The Break-Even Analysis (BEA) tells you when your investment will be repaid and when you'll start making money. In most cases, the power system's breakeven point is expressed in years. It differs from the payback time in that it is a little longer. We use Rs. 13/kWh in repayment as decided by national regulator, but we use nearly Rs.17/kWh here because this is a savings decided by market. Each system's net capital cost and annual savings were calculated for BEA. The payback calculation is identical to the net capital cost, while the savings, on the other hand, are determined by multiplying the kWh/year produced by Rs. 17/kWh.

The BE Point is calculated using the formula:

$$BEA = \frac{\alpha \sum_{i=1}^{20} G_i - SV}{\gamma G_r}$$

Where,

- α Estimated system cost per unit watt
- i No. of Pro(Con)sumer 1, 2, 3 ...
- G_i Installed Generation Capacity of ith pro(con)sumer
- r Depreciation Rate
- y Expected Lifespan of the system in yrs
- SV Salvage Value of the system
- β Price per unit watt for sale
- γ Saved per unit watt
- Gr Yearly kWh Produced

C. Levelized Cost of Energy

The term "levelized cost of energy" (LCOE) refers to the cost of solar power produced over a period of time, usually the system's usable life. We calculated the capital costs of both systems for a period of 25 years for this analysis. This analysis also includes the cost of operation and maintenance. Following the discovery of capital investment, we computed the number of kWh generated over a 25-year period (Useful life of the system). The LCOE is determined using the formula below.

$$LCOE = \frac{p \sum_{i=1}^n G_i}{(1-r)^y} + \frac{\sum_{j=1}^{\zeta} O_m}{\zeta G_r}$$

Where,

- p Estimated cost of the system per unit over a 25-year period
- i Pro(Con)sumer 1, 2, 3 ... n
- G_i Generation installed Capacity of ith pro(con)sumer
- r Depreciation Rate
- y Expected Life of the system in yrs
- O_m Estimated cost of O&M
- ζ The whole system's life span is 25 years.
- G_r Yearly kWh Produced

IV. RESULTS AND ANALYSIS

The results are obtained by rigorous computation, using the formulae discussed in section 3 and aided by a variety of data tables. Based on these results a comprehensive analysis has been carried out. Both systems are compared based on cost per unit watt analysis, payback analysis, break-even point analysis and LCOE analysis; which is discussed hereunder.

A. Cost Based Comparative Analysis

The cost of Net Metering and Blockchain systems is compared using a Radar chart based on the cost of four layers. The cost of the control layer and power layer for both systems is practically identical, as seen in the graph. This is owing to the fact that the architect of both at power level are identical, with the cost per watt of the power layer being Rs. 90.67 each. The control layer, on the other hand, differs just slightly, with NMS charging Rs. 19.75 and BCS charging Rs. 20.19.

The communication and business layers, on the other hand, are more expensive in Blockchain than in NMS. Due to its intricacies, the communication layer has a cost per watt of Rs. 8.59 in BCS and Rs. 5.49 in BCS. As a result, the findings of the cost comparison demonstrate that the initial investment in NMS is lower than that in BCS.

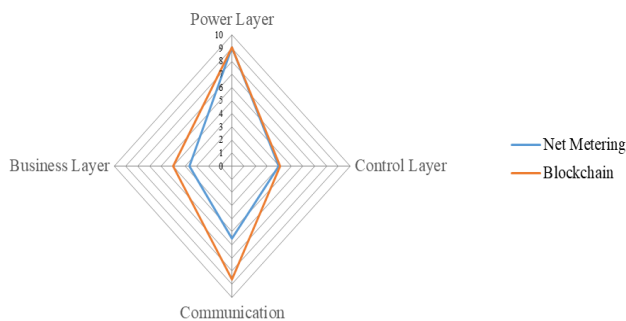


Figure 1. Comparative Analysis of NMS and BCS on Cost

However, because the difference is so small (i.e., only Rs. 3.66 per watt), the BCS should not be rejected outright at this

stage. As a result, we conducted additional study using economics toolbox, which is explained in the following sections, and the results are really fascinating.

B. Payback-Based Comparative Analysis

For payback, the formula discussed in section 1.3.1 is used, where the yearly electricity cost is computed by multiplying the annual energy use in kWh with the annual electricity tariff. The annual profit of net metering is computed by multiplying the number of kWh generated by the selling price per unit (Rs. 13/kWh currently in Pakistan). The net outcome of the previous two values resulted in annual trade bill. The installed capacity and the cost per watt are used to compute the capital cost of NMS. The salvage value is computed using the cost per watt of the salvage value multiplied to the installed capacity of each prosumer. Finally, results are obtained using the said formula and graphically demonstrated as:

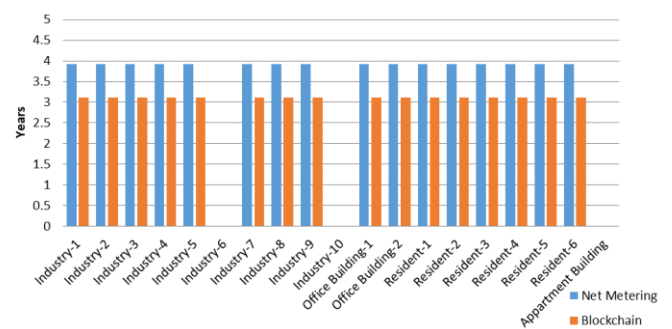


Figure 2. Comparative Analysis on the basis of Payback

The payback period for NMS is longer than that of Blockchain, as evidenced by the outcomes. NMS has a 4-year repayment time, while BCS has a 3-year payback period. The rationale for this is that the Blockchain income model appears to be more viable, profitable and market oriented. The NMS revenue model is fixed at Rs. 13 per unit, whereas the BCS unit cost varies with market conditions but is always higher than NMS, resulting in a shorter payback period.

C. Breakeven Point Based Comparative Analysis

The break-even analysis is discussed in detail in section 1.3.2, here we shall discuss the results. Net capital cost is obtained in the same way as that of payback. Using the annual savings and capital cost, we calculated the BEP. In the following bar chart, the results are compared.

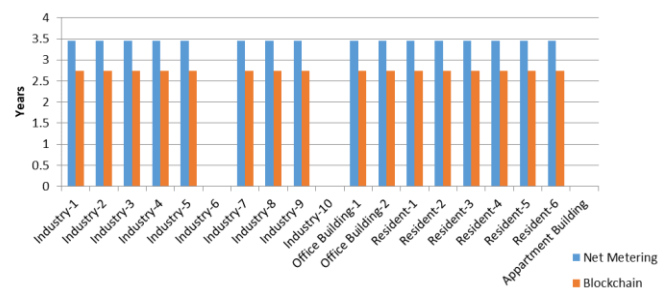


Figure 3. Breakeven point-based comparative analysis

The chart shows that Blockchain is better than NMS because in NMS the BEP reaches in more time than Blockchain. The BEP is 3.45 years for NMS, and 2.74 years for Blockchain. Therefore, in terms of BEP Analysis, BCS is better than NMS.

D. LCOE-based Comparative Analysis

The levelized cost of energy, discussed in section 1.3.3, tells how much each unit will cost us. For the LCOE the cost of entire system life is estimated for each system. Because the various elements in NMS and BCS have a different lifetime, a benchmark for 25 years is considered as the system life and the number of substitutions a component might need is accounted for; Like for a 5 years of the inverter life, we will need five substitutes throughout our lifetime. The generation of energy in useful life is estimated after the cost of the system is determined. The LCOE is calculated and the findings are presented below.

The chart shows that Blockchain's LCOE is Rs. 3.67/kWh, while Rs. 3.78/kWh for NMS. Therefore, in terms of LCOE, the BCS is also better than NMS.

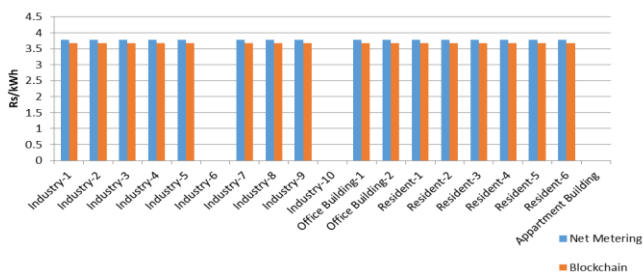


Figure 4. LCOE-based comparative analysis

CONCLUSION

It is concluded for the detailed analysis that the Blockchain-based energy sharing system outperforms the NMS. The following radar charts compares both system in regards of our findings. The payback analysis clearly shows that Blockchain outperforms NMS. BEP reaches BCA earlier than NMS implying a better performance in BEA for the Blockchain. The LCOE of Blockchain is lower than that of NMS, implying that BCS is less expensive per kWh than NMS. The Rate of Return of BCS is higher than that of NMS, indicating that BCS offers a better return than NMS. The only metric in which NMS outperforms BCS is cost per watt analysis, which is owing to the complexity of BCS being a little higher. Thus, an energy sharing mechanism based on Blockchain technology is recommended for modernising the grid.

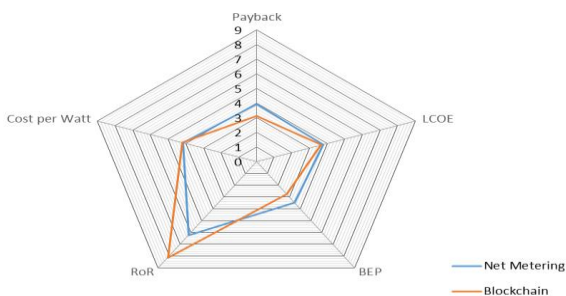


Figure 5 Net Metering Based Microgrid vs Blockchain Based Microgrid Comparison

Technological advancements have a broad scope in terms of experimental, analytical, field cases and numerical studies in complex petroleum engineering projects. These can be pertinent to transportation system and gathering and safety in oil and gas production. The current research was aimed at examining the challenges pertinent to safety prognostic technology as well as various ways in which it can be implemented for resolving issues in complex petroleum engineering projects. For the conduct of this research, qualitative methodology was used and primary data was assessed to present critical evaluation of the stated aim. The interviews were conducted from 10 petroleum engineers working in different public and private companies in Pakistan. The snowball technique followed by thematic analysis data analysis technique was applied for the generation of primary findings. The results of the research examined that safety prognostic technologies are significant in terms of enhancing safety, reliability and reducing the possible errors in maintenance. It has further examined that in complex engineering systems, there are multiple propagation paths to different consequences some of which might differ with respect to the most single faults.

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